

Objective Drought Classification

Kingtse C. Mo

CPC/NCEP/NWS

and

Dennis P. Lettenmaier

University of Washington

Current status of drought monitoring

- Currently, Drought monitoring is based on three drought indices :
 - Standardized precipitation index (SPI)- P deficits
 - Soil moisture (SM) percentile (SMP)- SM deficits
 - Standardized runoff index (SRI)- streamflow deficits
- SM and runoff are taken from the NLDAS
- Usually, the ensemble mean SPI6, SRI3 and SMP are used for monitoring

The EMC NCEP system

- Four models: Noah, VIC, Mosaic and SAC
- Climatology: 1979-2008
- On 0.125 degrees grid
- P forcing : From the CPC P analysis based on rain gauges with the PRISM correction.
- Other atmospheric forcing: From the NARR

The University of Washington system

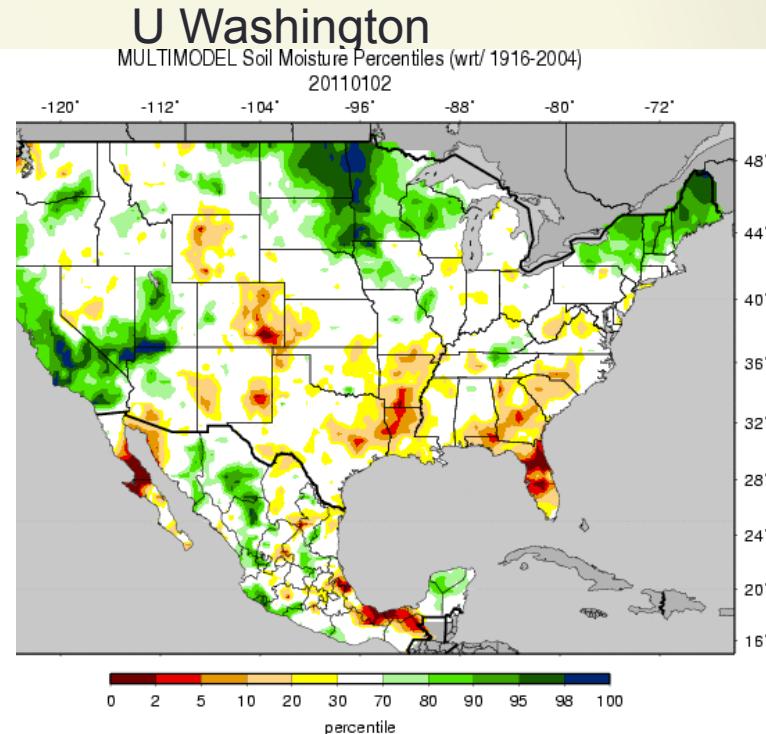
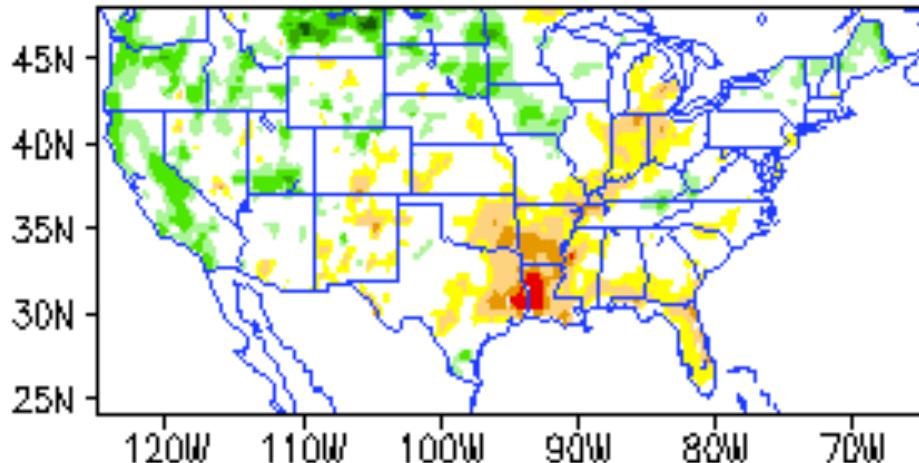
- Four models: Noah, VIC, SAC and CLM (different versions)
- Climatology: 1915-2008
- On 0.5 degrees grid
- P, Tsurf and low level winds are derived from the NOAA/NCDC co-op stations
- P from index stations

Different systems are able to select the same drought event, but they may not classify drought in the same category

Multi model ensemble SM %

EMC

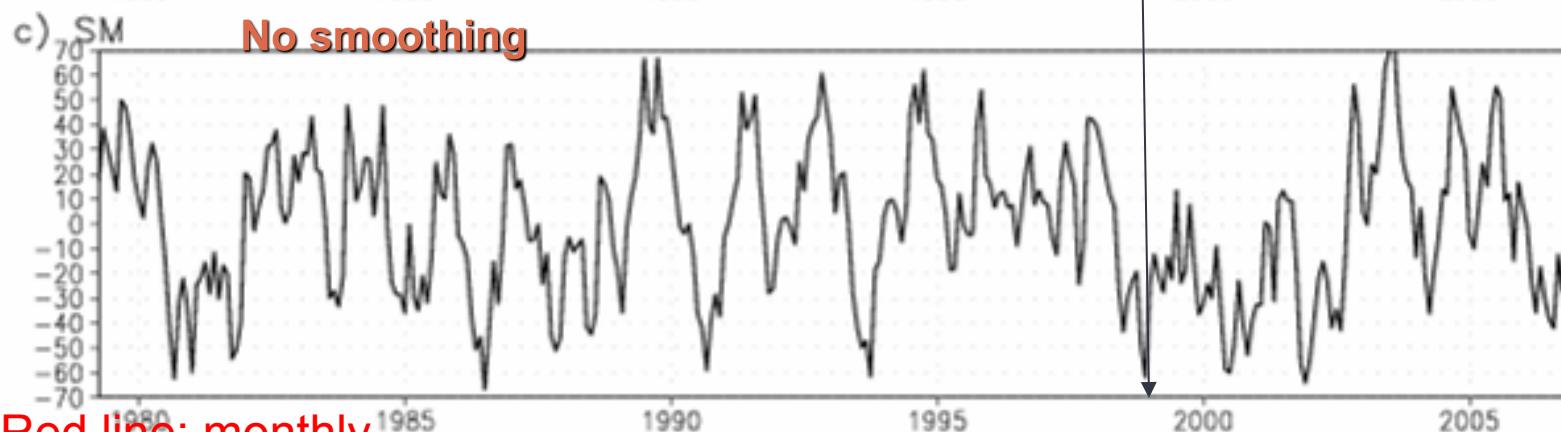
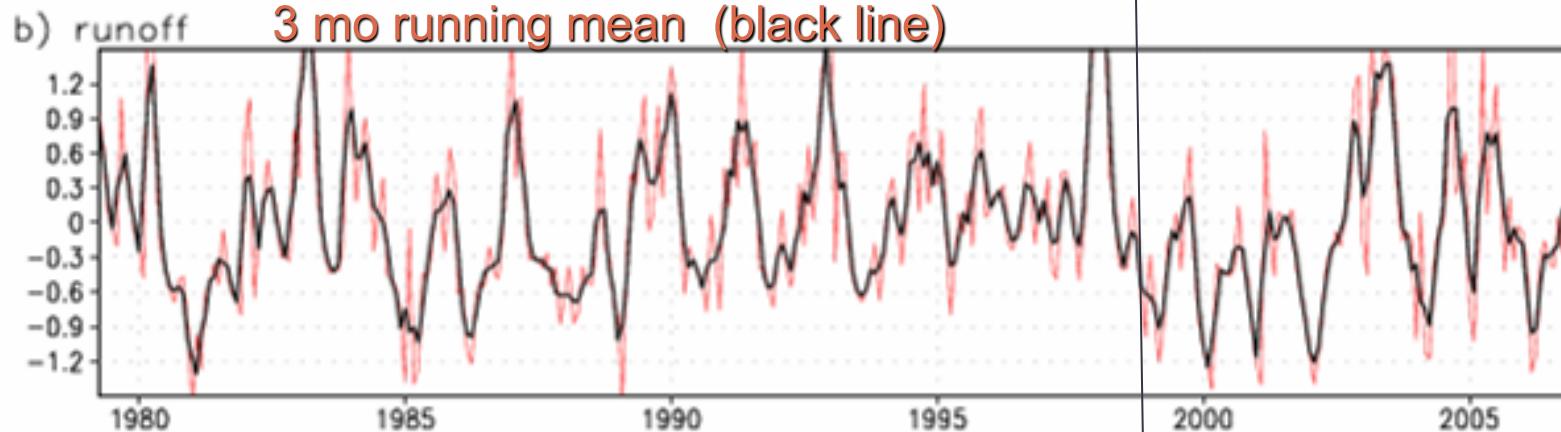
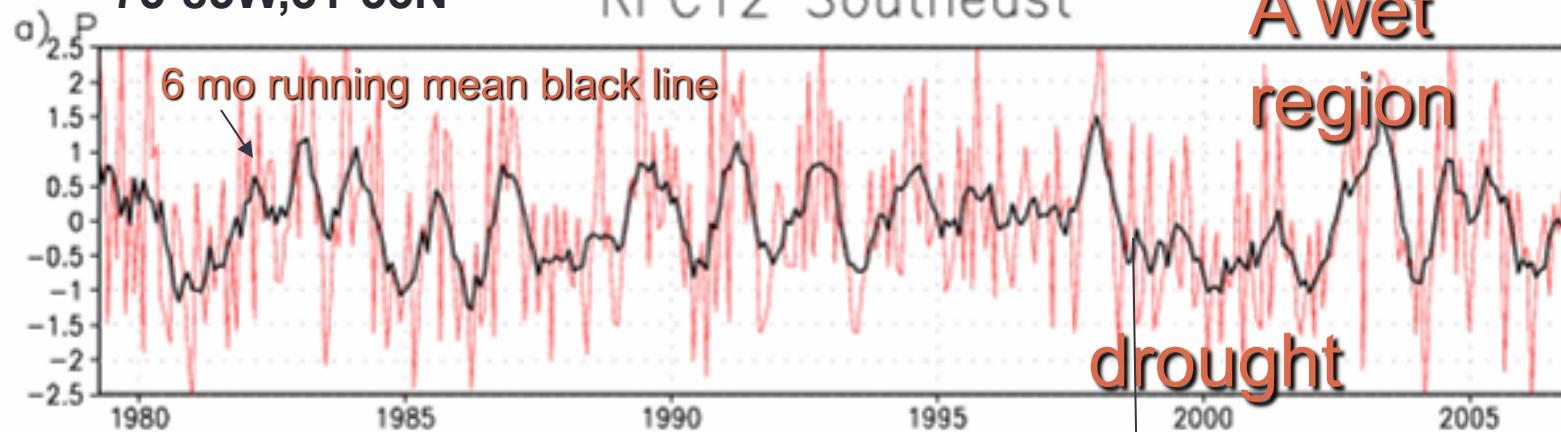
Ensemble



1. The patterns are similar, but magnitudes are differences:
2. Over Dakotas and Minnesota, percentiles are higher on the UW map,
3. Over the Southeast, UW percentiles are also higher

75-85W,31-35N

RFC12 Southeast



Red line: monthly
mean, no smoothing

SM 1-2 months delay

Challenges

- There are large uncertainties in the drought indices
- Uncertainties come from
 - 1. different NLDAS systems, land models, input data
 - 2. different scales of indices
 - e. g. SM may lag the SPI6 at the onset / demise stage of drought

Status

- All indices are able to select the same drought event, but **uncertainties are too large to classify drought** in the (D1, --- D4) categories.
- We are not able to give risk managers the best and worst scenarios and the occurrence probability.

Possible solutions

- Joint distribution: AghaKouchak (2012)
- Youlong Xia – reconstruct DM
- Ensemble means (Dirmeyer et al. 2006)
 - The averaging process decreases the magnitudes of the ensemble mean
 - How to assess the uncertainties of the ensemble mean?
 - A probabilistic approach

Data used for this study (total 18 fields)

- SPI – two sets :
 - (1) the UW index stations
 - (2) the CPC unified analysis
- Soil moisture SM- 8 sets:

4 models from the NCEP/EMC NLDAS (Noah, VIC, Mosaic, SAC)

4 models from the UW NLDAS (Noah, VIC, CLM and SAC).
- Runoff-8 sets: same as SM
- Period: Jan 1979– Nov 2012
- Resolution: 0.5 degrees

procedures

Grand mean index as the major indicator

- Form ensemble mean for P, SM and runoff
- Calculate the drought index (SPI6, SMP and SRI3) from the corresponding mean time series
- Put indices in percentiles
- grand mean index=> Equally weighted mean of SPI6(en), SMP(en) and SRI3(en)

Drought categories

- The drought category is assigned according to percentiles: (Svoboda et al. 2002 BAMS)

2% or less---D4;

2-4.9 %---D3;

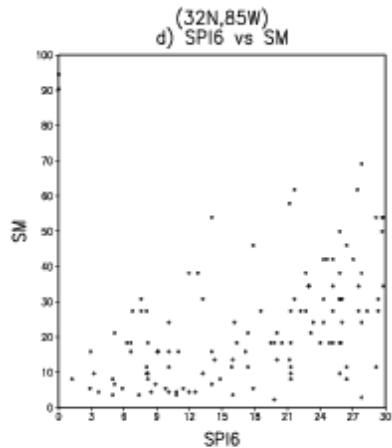
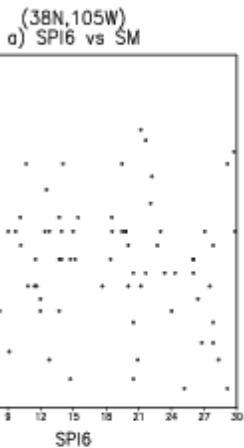
5- 9.9%---D2;

10-19.9%---D1;

20-30%----D0

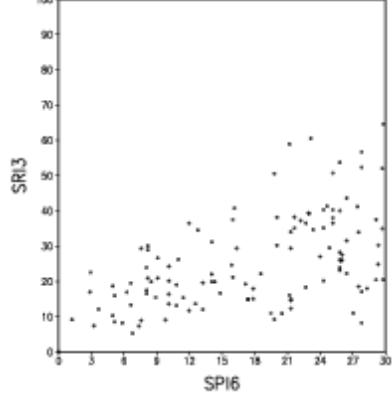
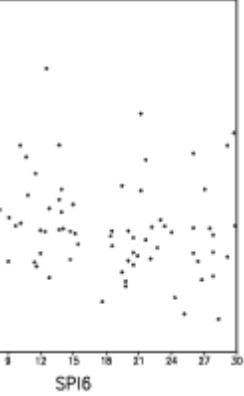
(38N,105W)
a) SPI6 vs SM

(32N,85W)
d) SPI6 vs SM



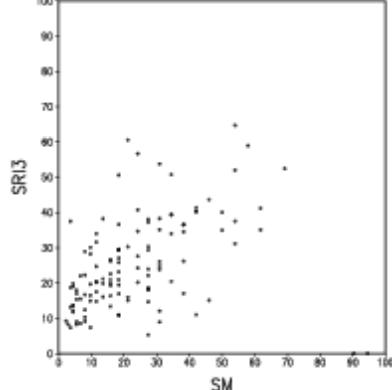
b) SPI6,SRI3

e) SPI6,SRI3



c) SM vs SRI3

f) SM vs SRI3



How dependent are
these indices when
under drought?

At each grid point, we
plotted scatter
diagrams for two
indices when SPI6 is
below 30%

At the extremes, the
indices do not have
systematic
relationships

grand mean drought index western drought

a)200001

f)200110

k)200210

b)200004

g) 200201

l)200301

c) 200010

h)200204 2.SW

m) 200307

1.PNW

d)200101

i) 200206 3. return

j)200206

n)200310

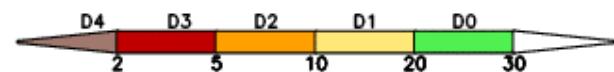
e)200103

j)200207

o)200401

l)200207

p)200401



Grand mean index

1. It captures the evolution of drought well;
2. Three episodes
 - 2001 winter PNW
 - 2002 summer: Southwest
 - 2003 return of drought

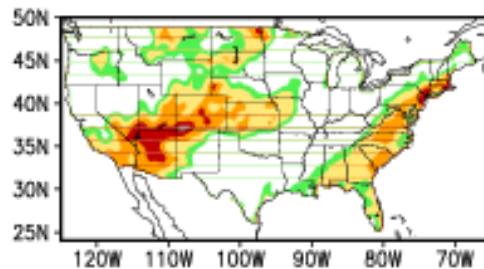


The month that the state declared drought emergency

Uncertainties of indices

SPI6(en)

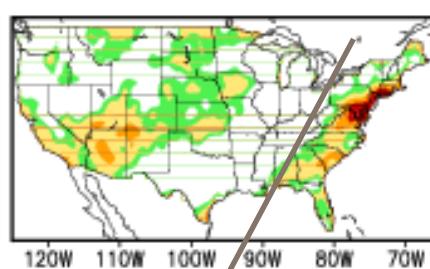
c) 200204



SRI3(en)

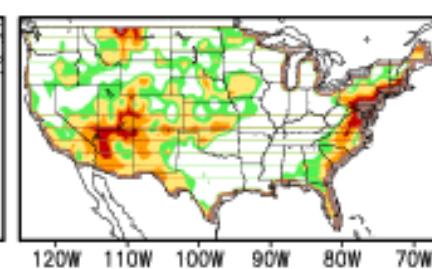
h) 200204

D0-D1



SMP(en)

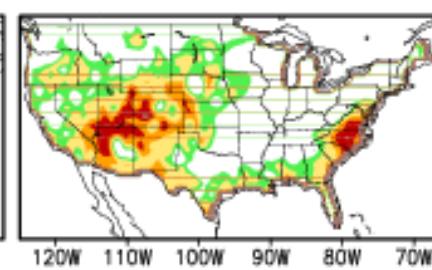
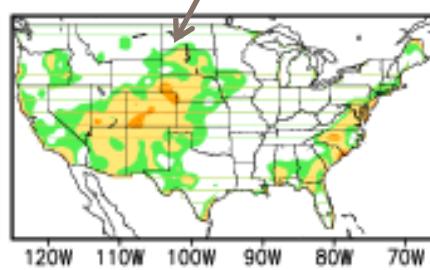
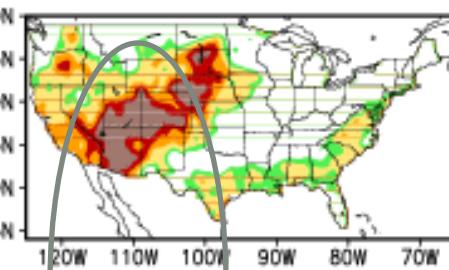
m) 200204



d) 200206

i) 200206

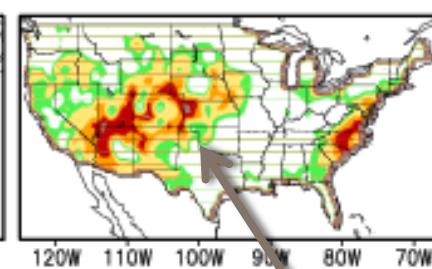
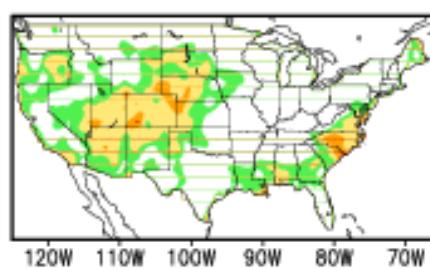
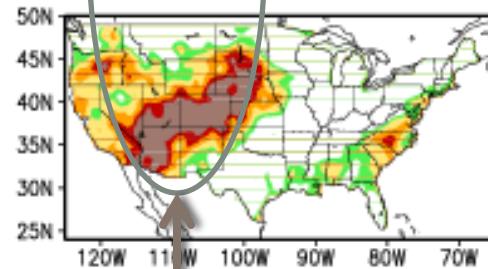
n) 200206



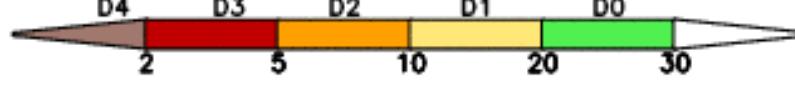
e) 200207

j) 200207

o) 200207



D4

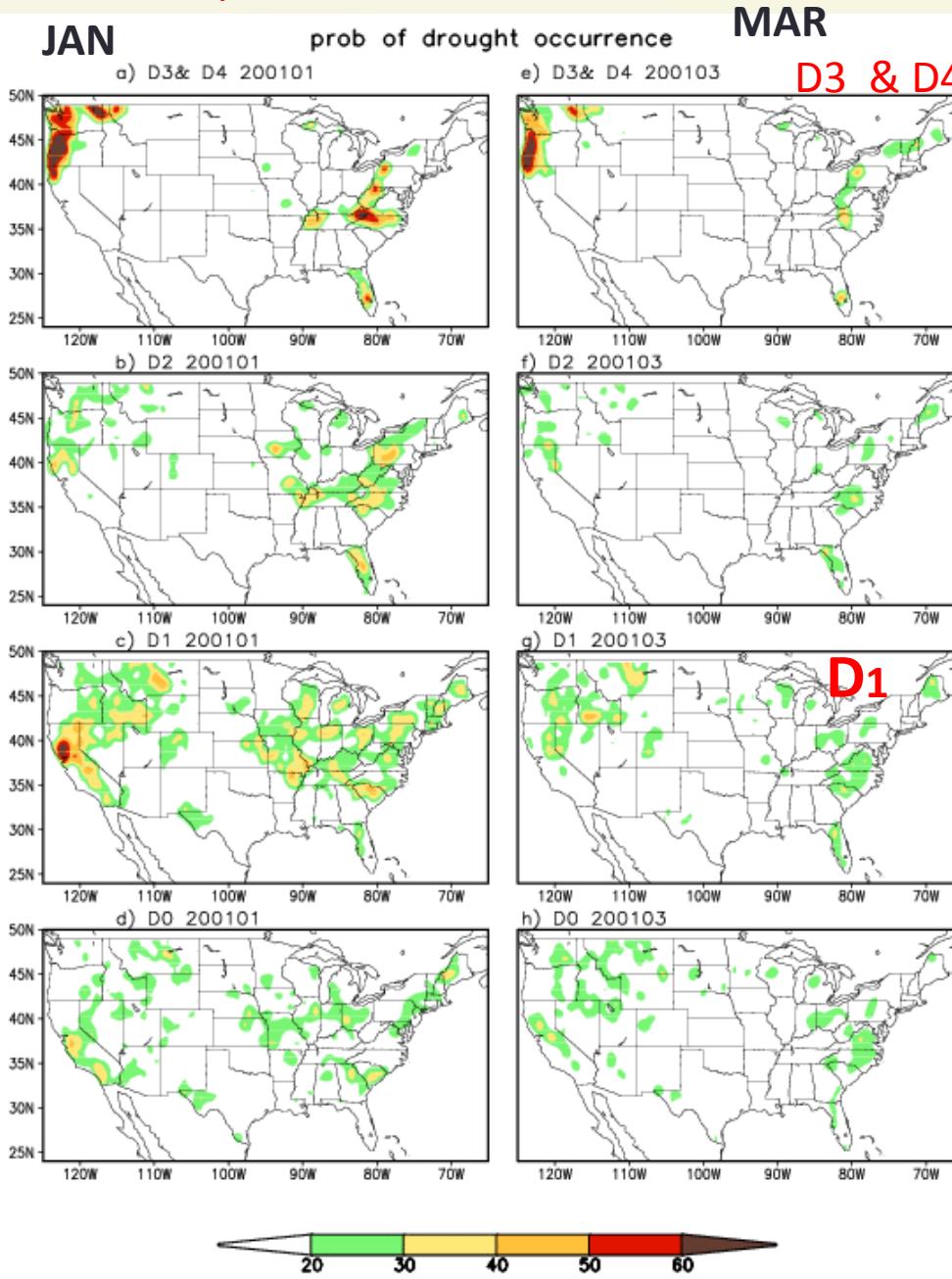


D2-D3

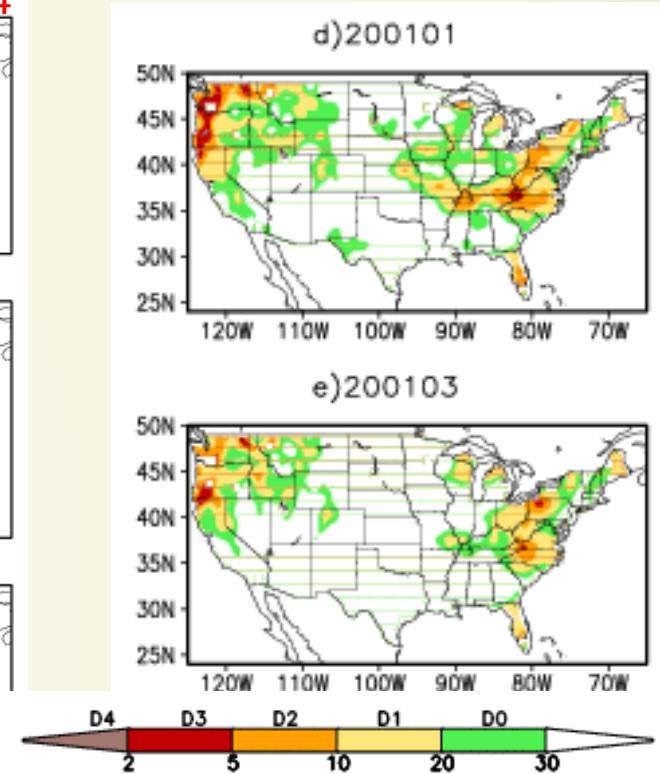
Probability of drought occurrence in each drought category D0-D4

- Original time series :18 variables=> 18 indices in percentiles
- The drought category is assigned according to percentiles:
- For a given month , we count the number of indices in each category for each grid cell. e.g.
- $N(D1)$ for the number of indices in D1 category. Then the probability of D1 occurrence is
 $P(D1)= N(D1) *100/\text{total number of indices},$
- The probability of the total drought occurrence D_{total} is the sum of $P(D0)$ to $P(D4)$

PNW episode



Grand mean index



Most possible scenario

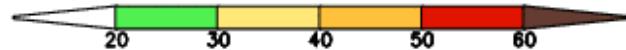
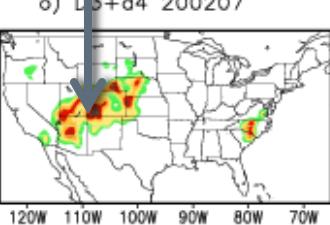
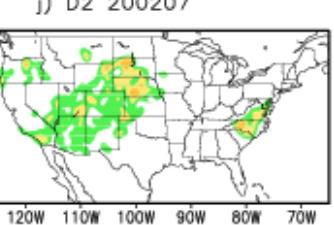
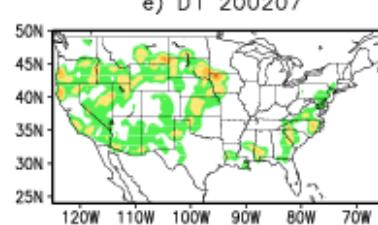
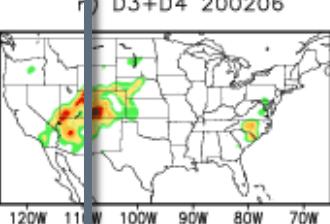
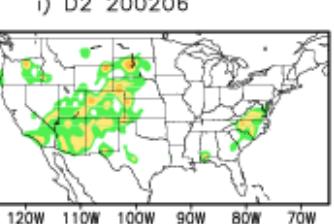
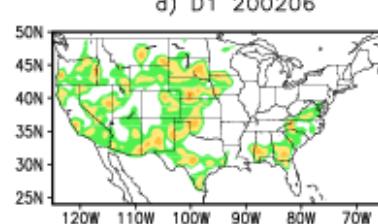
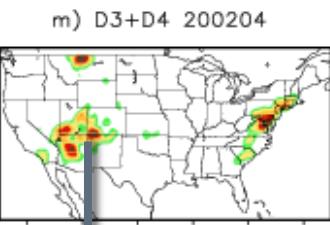
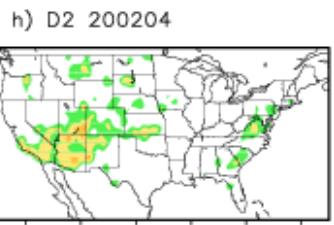
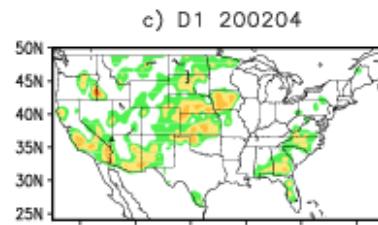
1. D3 or D4 for winter 2001 over the coastal areas of the PNW
2. Drought over the inland Missouri basin was weaker
It was not in D3 or D4
1. It is likely in D1 with a 20-40% prob

Prob of drought occurrence in

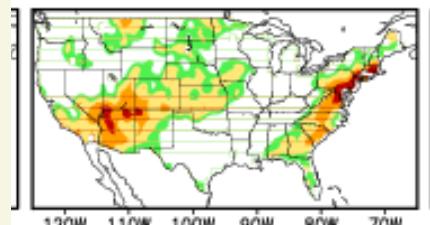
D1

D2

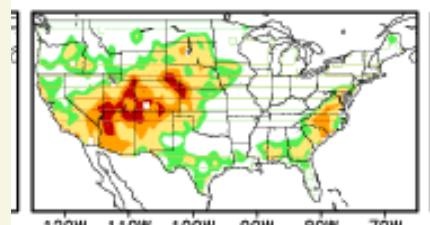
D3 & D4



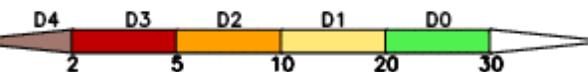
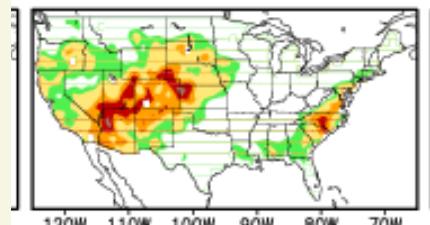
Grand mean index



i) 200206



j) 200207



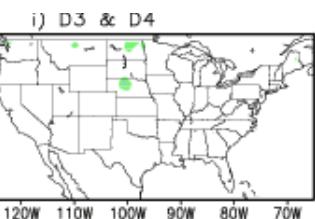
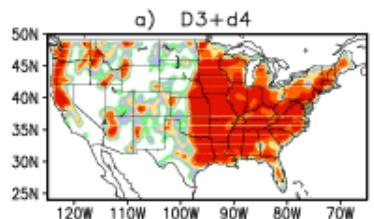
1. Intensified from spring to summer
2. In the Four Corners, the drought was in or above D2 : a 40-60% prob for D3 or D4 drought to occur
3. Outside of the core region, only D1 (**more regional details**)

grand mean index in the Y category

Grand mean D3 & D4

D2

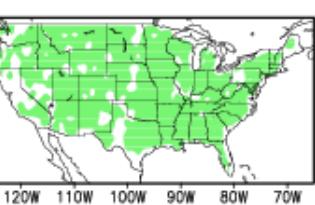
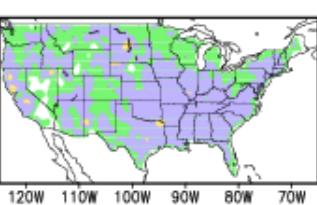
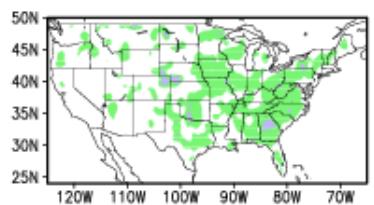
D1



b) D2

f) D2

j) D2

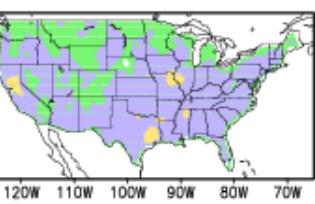
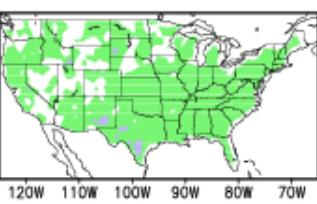
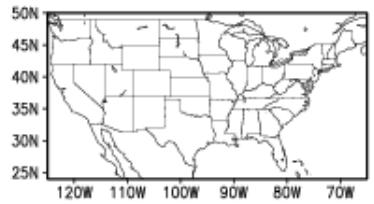


X category

c) D1

g) D1

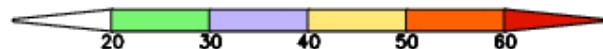
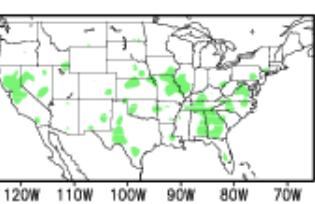
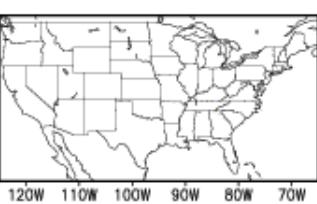
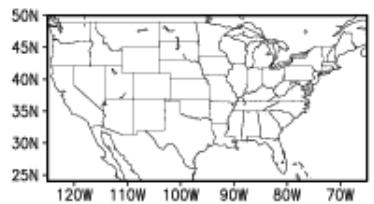
k) D1



d) D0

h) D0

i) D0



Grand mean index & Prob of drought occurrence

D3
&
D4

Prob of Occurrence in x category when the grand mean index is in the y category

D2

D1

D0

1. When the G index is in the D3 & D4, a 50-70 % prob is in the D3 and D4;
2. When G index is in D1, Prob is 30-40% in D1 and 20-30 % in D2
3. if G index is in D2, equally likely in D2 or higher

What do we learn?

1. The grand mean index captures the drought evolution
2. The grand mean index along with the prob is a good approach to classify drought
3. At the extremes, grand mean index in D3 or D4, more than 60% of prob in D3 and D4
4. **The grand mean index has a tendency to underestimate drought intensity.**
5. The prob can also discriminate : give the scenario that is unlikely to happen
6. It shows more detailed regional features.

Advantages of the probability approach

1. The grand mean index should be analyzed together with the probability of drought occurrence in each category.
2. Detailed regional Information
3. Take into consideration of the uncertainties in the NLDAS and different drought indices.
4. To give risk managers the best/worse situation with the probability for it to occur
5. A better way to analyze a drought event: area coverage. Duration and drought evolution